Comparison of the vegetation of the islands in Shoalwater Bay (Rockingham, Western Australia) with that of the coastal bushland

E Rippey[1,2], J J Rippey[2], B Green[2] & J N Dunlop[2]

[1]Department of Geography, University of Western Australia. Crawley WA 6009
[2]Friends of the Shoalwater Islands Marine Park, % Rockingham Environmental Centre, Safety Bay Road, Rockingham WA 6168
email: jjrippey@cyllene.uwa.edu.au

(Manuscript received May 2002; accepted November 2002)

Abstract

Surveys were conducted of the vegetation of three areas in and around Shoalwater Bay: a strip of foreshore (Mersey Point), a headland (Point Peron), and a string of islands. Each survey area measured about 15 ha. The differences between the two mainland reserves and the islands are of particular interest. Only 23% of the plant species recorded occurred in all three reserves. It appears that human activities have been directly responsible for many of the changes in the flora of the mainland reserves, while seabirds influence the plant cover of the islands. At Mersey Point, a large proportion of species appear to have been introduced by the dumping of garden rubbish. At Point Peron, the vegetation has been affected by frequent fires, so that fire-resistant species are favoured. On the islands, seabirds play a major role in determining the nature of the vegetation by virtue of their trampling and the guano that they deposit. The findings of this investigation provide a baseline for further monitoring and for evaluation of future management measures.

Keywords: Shoalwater Bay, coastal vegetation, island vegetation, Western Australia

Introduction

Shoalwater Bay lies off the west coast at Rockingham, 50 km south of Perth. It is enclosed to the east by the mainland beach, to the west by a string of small islands, and to the north by the Point Peron Peninsula (Fig 1). Mersey Point Reserve, a narrow foredune strip occupying the southern end of the mainland beach, Point Peron the rocky headland at the tip of the Cape Peron Peninsula, and the vegetated islands (Penguin, 12.5 ha; Seal, 1.2 ha; Bird, 0.9 ha; Middle Shag, 0.4 ha) make up the three reserves under consideration. Each covers about 15 hectares. All three areas have been registered as regionally significant under the state Bush Forever programme (Anon 2000).

The aim of this study was to survey the flora of the three reserves, to investigate the reasons for differences between them, and to look at the management implications. Bushland remnants are considered valuable for two main reasons (Briggs 1984). The great majority of the Perth metropolitan area has been cleared, and these remnants provide the best indication available of the composition of the pre-existing vegetation at any particular site. The reserves also provide habitat for native fauna, that is of particular value if there are links by corridors to other bushland remnants. Such links effectively enlarge the area of bushland, providing a larger genetic pool for uncommon species with the corridors allowing free movement of birds, pollinators, seed distributors *etc.* Point Peron and Mersey Point Reserves both have links with other bushland, as they form the extremities of a 200 ha reserve, albeit with narrow corridors.

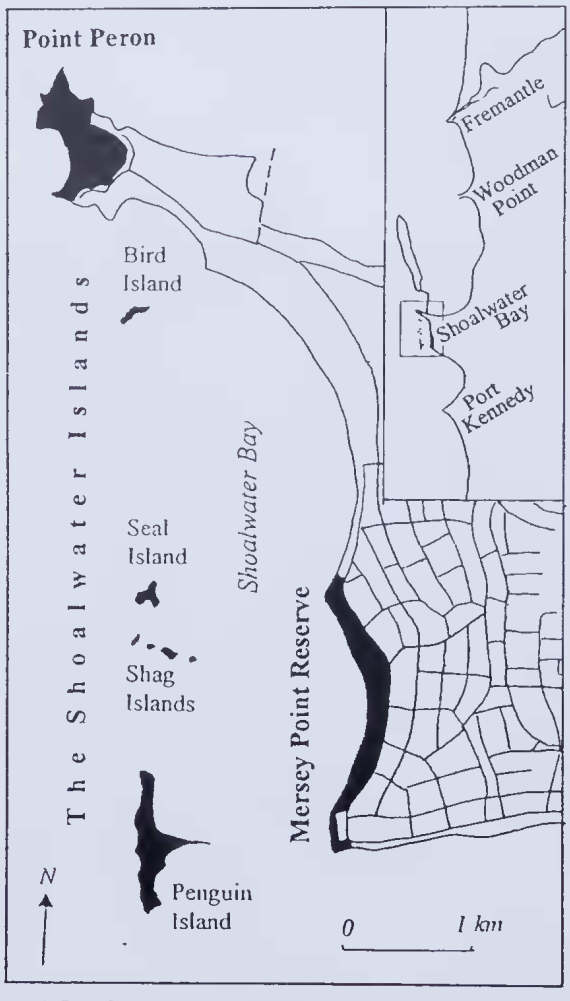

Figure 1. Locality map showing Shoalwater Bay surrounded by Mersey Point Reserve, Point Peron and the Shoalwater Islands.

© Royal Society of Western Australia 2002

Work on urban bushland shows that bush remnants suffer constant disturbance, mainly associated with human activities such as increasing fragmentation by paths and clearings, enrichment of the naturally low nutrient soils, frequent fires and the introduction of exotic species, both plant and animal (Piggott & Loneragan 1995). Some disturbance appears to be necessary to maintain species diversity, but frequent or intense disturbance decreases diversity (Hobbs & Huenneke 1992).

The Shoalwater Bay Reserves have all been subject to a century of severe disturbance. Holiday makers have used the area extensively and their activities were largely unrestricted until the late 1980s. Much of the surface of all three areas has been denuded at various times. The central eastern part of Mersey Point Reserve, which originally consisted of high dunes, was bulldozed level in the 1960s to allow ocean views and easy access to the sea for the developing suburbs of Rockingham. Point Peron was the site of an artillery battery during World War II. On Penguin Island the north and south plateaux were scraped clear by guano collectors early in the twentieth century (Chape 1984) leaving large areas still denuded in the 1950s. Human impacts are less dramatic at present, particularly on the islands, where the only access permitted is to parts of Penguin Island. Despite this protection, however, the islands are especially vulnerable to disturbance, as they form what is effectively a fragmented reserve with a very high edge to area ratio. Mersey Point also has a high edge to area ratio owing to its elongated shape.

For the three Shoalwater Bay Reserves, disturbance falls into three main categories, fire, nutrient enrichment and weed invasion.

Fire

The frequency of fire in bushland areas in Perth can be correlated with proximity to urban development and the level of human activity (Piggott & Loneragan 1995). Kings Park experienced 10 fires *pa* between 1944 and 1994 (Dixon *et al.* 1995), Star Swamp Bushland Reserve about one *pa* between 1948 and 1987, and still fewer occurred at the outlying Woodman Point and Yule Brook Reserves (Piggott & Loneragan 1995). About 50% of fires in Kings Park are the result of arson (Dixon *et al.* 1995), and for the Perth region as a whole 30% of fires are arson-related with another 30% having escaped from control burning or burning of rubbish (Robley 1983). The responses of different native species to fire differ (Wycherley 1984), and frequent burning can change the composition of the flora. Species that can respond rapidly are advantaged, particularly native species capable of resprouting such as *Acacia rostellifera*, and exotic species of both annuals and resprouting perennials. The most vulnerable species are obligate reseeders that are killed by fire, such as *Templetonia retusa*. These take several years to replenish the seedbank and progressive loss of species can result from repeated burning (Ford 1985). Fire is not common on the offshore islands, and there is no record of wildfire on the Shoalwater Islands.

Soil enrichment

Here again the processes on the islands are very different from those in the mainland reserves. On the mainland the native plants are suited to soils that are naturally low in nutrients, and enrichment occurs as a result of human action, for example, through fertiliser run-off from adjacent grassed areas or from dumping of garden rubbish (Hobbs 1995a). Mersey Point is at risk as it encompasses several pockets of lawn and the reserve lies opposite a row of suburban gardens.

On the islands the situation is different. Some of the problems of lawned areas adjacent to bushland probably exist around the lawn on Penguin Island, but there is enormous enrichment of much of the soil from the guano of thousands of seabirds, which use the islands for nesting and roosting. The number of pairs of pied cormorants (*Phalacrorax varius)* nesting on the islands has increased from a total of about 150, nesting on one island or another in the 1940s, to about 1000 distributed between all islands each year (Rippey *et al.* 2002a). Pelicans (*Pelecanus conspicillatus*), the other major guano producers of the region, have nested here since 1999 and silver gulls (*Larus novaehollandiae*), none of which nested on Penguin Island in the 1940s (Serventy & White 1943) now number thousands of pairs (Dunlop *et al.* 1988).

Little has been written on the ecology of Perth's seabird islands compared with that of urban bushland areas, but an ecological cycle was described by Gillham (1961). She suggested that the climax community of native shrubs, including *Nitraria billardierei*, was damaged or killed by trampling and droppings during a nesting episode, and was replaced by coprophilic native species, especially *Malva australiana*, until recovery of the climax community occurred. Further nesting sometimes left nothing but annual weeds or even bare ground, at which stage the area became unsuitable for nesting, and recovery commenced.

Weed invasion

Over 1000 introduced plant species have become naturalised in Western Australia, more than half of which are present in bushland (Keighery 1994) or natural ecosystems and are termed environmental weeds (Humphries *et al.* 1991). Key stages in the establishment of weeds have been identified (Anon 1999) whereby species are introduced, become established, produce a large number of propagules, and after what may be a considerable time lag, disperse, sometimes through 'nascent foci' of outlying populations (Hobbs & Saunders 1995).

The ability of exotic species to invade is a function of the characteristics of both the species and the site invaded (Hobbs & Huenneke 1992). Davis *et al.* (2000) suggest that a surplus of available nutrients in an area underlies invasion, and Hobbs (2000) refines this by suggesting that disturbance which increases the supply of a limiting resource favours invasion. While disturbance can take many forms (for example fire, grazing, soil disturbance, nutrient inputs, trampling, fragmentation), weed invasion is particularly enhanced by a combination of soil distubance and increased nutrients (Hobbs & Huenneke 1992).

Plant invasion can affect the environment at three levels. At the genetic level the number of individuals of native species can be reduced below the minimum necessary for persistence, at the species diversity level

the number of species present and their distribution can be reduced, and at the ecosystem level the functioning of the ecosystem can be changed. Thus the ability of native species to survive, and their abundance, can be reduced, fire regimes can be altered, and even nutrient cycling, hydrology and energy budgets can change (Mack *et al.* 2000). Geomorphological processes can also be altered, and the problems of plant invasion and the difficulty of repair are greatest where ecosystem function is damaged (Anon 1999).

Locality and Methods

During 1997-1999, the Friends of the Shoalwater Islands Marine Park conducted botanical surveys of the Mersey Point reserve, Point Peron and the Shoalwater islands. The names of non-native species are preceded by an asterisk (*).

Locality

The reserve at Mersey Point consists of a narrow foreshore 1.6 km long between the beach and the sea-front houses of Rockingham. Point Peron has a coastline of rugged cliffs with a beach to the south-west, and undulating dunes to the east. The islands consist mainly of sandy plateaux surrounded by cliffs up to 5 m high undercut by the sea, and talus slopes where caves have collapsed. There is a west-facing beach on Penguin Island and eastern beaches on Penguin and Seal Islands.

The geology of the area consists of aeolianite limestone overlain by calcareous sand dunes. The islands and Point Peron are remnants of a limestone ridge, parallel to the mainland, partially inundated at the start of the Holocene. The ridge eroded and the sand was deposited on the mainland shore ten kilometres to the east. The mainland coast has prograded during the Holocene to within a kilometre of the string of islands, which are now linked by sandbars, and in the case of Point Peron by a peninsula, to the mainland. The sandbar to Penguin Island from Mersey Point can be crossed on foot at low water.

Climate

The climate is Mediterranean with over 800 mm rain *pa*, falling mainly in the cool winter months, while summer months are dry, windy and hot with daily maximum temperatures averaging 30 °C in January and February. Salt is blown in from the sea and some 200 kg is deposited on every hectare annually (Hingston & Gailitis 1976). All three areas are subject to the influence of waves and the prevailing south westerly winds.

Tenure

Mersey Point is a C Class reserve vested in the Shire of Rockingham for the purpose of recreation. The reserve encompasses three car parks, one with a tea-room and landscaped garden, one with an informal boat ramp, and the third with a lawned picnic area. There are several walkways to the beach.

Point Peron is a C Class reserve vested in the Ministry for Sport and Recreation for the purpose of recreation. It is managed by the Department of Conservation and Land Management under a Cabinet Agreement pending completion of a management plan. Rehabilitation work has been carried out recently, with revegetation and installation of paths and fences.

Penguin Island is an A Class reserve managed by the Department of Conservation and Land Management for the purpose of recreation. The smaller islands are A Class nature reserves for the conservation of flora and fauna. Public access is only permitted to Penguin Island, where visitors are restricted to the beaches, a lawned recreation area on the eastern tombolo, and two boardwalks between the eastern and the western beaches.

In October/November 1997 volunteers carried out a botanical survey of the islands in Shoalwater Bay. On Penguin Island, nine east-west transects consisting of a chain of plots 2 m wide by 5 m in length were used to record plant species and approximate percentage cover. Plants were collected and identified on the smaller islands with transects being carried out later by the authors on the longest axis on Middle Shag, Seal and Bird Islands. A herbarium of pressed plants was prepared and identification of the majority of species checked by the Western Australian Herbarium. Results (Rippey *et al.* 1998) are repeated here, with the addition of eight relics of earlier non-native plantings; **Araucaria heterophylla*, **Agonis flexuosa*, **Eucalyptus gomphocephala*, **E. utilis*, **Melaleuca lanceolata*, **M. nesophila*, **Tamarix* sp and **Ficus* sp.

A similar survey was conducted for the reserve at Mersey Point the following spring in October 1998 with four east-west transects. Follow-up collections were made later that month and in the following month with two traverses along the north-south axis. Species growing in watered, lawned areas were excluded.

One of the authors (BG) provided the initial plant list for Point Peron. She had organised the recent rehabilitation of the Point Peron reserve which involved research into the flora and collection of seed and cuttings for cultivation for later replanting. One east-west transect was carried out in October 1999. Numerous other visits were made to all three reserves during 2000 and 2001.

Plant nomenclature is taken from Paczkowska & Chapman (2000) and Bodkin (1993) in the case of **Agave attenuata* and **Sansevieria trifasciata*. Species lists were compared with lists of native species recorded from cuspate forelands situated to the north and south of the study area, Woodman Point (Powell & Emberson 1981) and Port Kennedy (Trudgen 1988) (see Fig 1).

In October 2001, soil samples were taken from Mersey Point, Point Peron, Middle Shag Island, the east and west parts of Bird Island and from the southern promontory and the eastern tombolo of Penguin Island. Samples could not be collected from Seal Island nor the northern promontory of Penguin Island as seabirds were nesting there throughout the spring. The sample from each area consisted of three cores of surface soil mixed together, each core measuring 5 cm in diameter and 10 cm in depth. Analysis was done by CSPB Futurefarm.

Results

Altogether 146 species were identified from the three sites, 76 species at the Mersey Point reserve, 86 species at

Table 1

Total number of native and alien species in each of the survey areas.

Location	Native	Alien	all spp
The islands	42	46	88
Mersey Point	28	48	76
Point Peron	40	46	86

Point Peron and 88 species on the Shoalwater islands (see Appendix). A total of 55 species (38%) were native and 91 (62%) were introduced. Mersey Point reserve has a higher proportion of introduced species than the other two areas (Table 1). About 23% of species collected are common to all three locations. This core group of 33 species consists of 18 native species (*Carpobrotus virescens, Alyxia buxifolia, Olearis axillaris, Senecio lautus, Rhagodia baccata, Threlkeldia diffusa, Lepidosperma gladiatum, Acanthocarpus preissii, Scaevola crassifolia, Conostylis candicans, Acacia cyclops, Acacia rostellifera, Myoporum insulare, Hardenbergia comptoniana, Spinifex hirsutus, Spinifex longifolius, Clematis linearifolia* and *Spyridium globulosum*) and 15 introduced species (**Tetragonia decumbens, *Trachyandra divaricata, *Arctotheca calendula, *Sonchus oleraceus, *Cakile maritima, *Euphorbia peplus, *Euphorbia terracina, *Fumaria capreolata, *Lagurus ovatus, *Pelargonium capitatum, *Romulea rosea, *Eucalyptus gomphocephala* (native to the Western Australian coast but planted in the areas surveyed), *E. utilis, *Stenotaphrum secundatum* and **Anagallis arvensis*).

These common species occur widely along the coast and the native species, in particular, account for the majority of the plant cover at the three Shoalwater reserves, and indeed for the coastal dunes of the Perth region. The natives are perennials and consist of 12 shrubs varying from prostrate to 5 metres tall, two climbers, one herb, two large grasses and a sedge. The aliens are mainly small annuals, with the addition of two low spreading perennials, two cormous species, a perennial grass and two trees.

Over 50% of the species recorded (77 of 146) only occurred in one of the three areas (Table 2). The differences between the numbers of native and alien plant species found at each location, and the numbers of each which are unique to that location, are not statistically significant using the χ^2 test ($P>0.05$).

Table 2

The number of species that only occur in one of the three survey areas.

Location	Unique Native	Unique Alien	Unique Total	Unique species as % of total species in that area
The islands	9	18	27	30%
Mersey Point	4	23	27	36%
Point Peron	7	16	23	27%
TOTAL	20	57	77	52%

Some species, such as **Araucaria heterophylla* (Norfolk Island Pine) and **Eucalyptus utilis* (Coastal Moort), are introduced species planted intentionally, while others such as **Eucalyptus gomphocephala* (Tuart) are native to the district but unlikely to be found naturally in this habitat. Bushland/urban interface areas such as these are often 'improved' and 'rehabilitated' over the years, thus it is not always easy to determine whether a species was brought in intentionally or arrived by chance.

Mersey Point

Of 76 species found at Mersey Point, 33 are the core species found in all 3 areas, and a further 35 are aliens, most which are common garden plants. Introductions include **Tropaeolum majus* (Nasturtium), **Agapanthus praecox* (Agapanthus), **Opuntia stricta* (Prickly Pear), **Lantana camara*, **Senecio tamoides* (Canary Creeper), **Cynodon dactylon* (Couch Grass), as well as a reed and several fleshy rockery plants. One of these succulent plants **Cotyledon orbiculata* had not been recorded as a weed in the Perth area previously but is a noted weed of offshore islands near Albany. All these weed species are well established and many are spreading. **Opuntia stricta* is forming a small grove of about 25 plants. **Schinus terebinthifolia* (Japanese Pepper), **Leptospermum laevigatum* (Victorian tea tree) and **Rhamnus alaternus* (Buckthorn) are large shrubs or trees that appear to be spreading and are considered a threat elsewhere (Hussey *et al.* 1997).

Point Peron

Acacia rostellifera thickets cover most of the Point, particularly to the east, and introduced annuals, particularly **Euphorbia terracina* and grasses, form much of the understory. Native shrubs on the higher dunes include *Acacia cochlearis, Melaleuca huegelii, Templetonia retusa, Spyridium globulosum, Olearia axillaris, Solanum symonii* and *Anthocercis ilicifolia*. A weed unique to this area is **Echium plantagineum* (Paterson's curse).

The islands

Eighty eight species were recorded for the islands, 85 of which are found on Penguin Island (including 8 planted species). A total of 24 species occur on the smaller islands, including *Malva australiana*, **Chenopodium album* and **C. murale* that were not recorded on Penguin Island.

Nitraria billardierei and *Rhagodia baccata* are natives that do particularly well on islands, but are less common (although widespread) along the mainland coast. *Nitraria* grows on the limestone talus slopes of all the Shoalwater islands. *Rhagodia* is a spreading shrub that covers a greater proportion of Penguin Island than any other species, although it is rare on the smaller islands.

Four Malvaceae are found on the islands. **Malva dendromorpha* is the dominant species on the small islands forming dense thickets 2 m high. **M. parviflora* forms restricted meadows on Penguin, Seal and east Bird Island. A few **M. linnaei* were located on Penguin Island. The native *M. australiana* was recorded in comparatively

Table 3

Soil composition in the three reserves; available nitrogen (nitrate N plus ammonium N), available phosphorus, and available potassium (mg kg^{-1}) and pH.

	N	P	K	pH
Mainland: Mersey Point	27	68	21	7.9
Point Peron	3	17	15	8.4
Penguin Is: southern promontory	19	314	34	7.7
eastern promontory	33	68	30	7.8
Bird Island west	288	771	259	7.1
east	477	767	1378	8.2
Middle Shag Island	499	850	737	6.7

small numbers on Middle Shag Island, and one plant was found on each of Seal and Bird Islands.

Most aliens on the islands are annuals, such as **Melilotus indica* and grasses **Lolium rigidum*, **Hordeum leporinum* and **Bromus diandrus* which can form lush meadows in the wet season. **Lycium ferocissimum* found on Penguin Island, is a dense thorny shrub which has survived attempts at eradication over three years.

Soils

Analyses of the soils taken from Mersey Point, Point Peron and the islands showed that available nitrogen, phosphorus and potassium levels tended to be very high on the small islands (Table 3).

Discussion

Inter-reserve comparisons can be helpful in assessing the completeness of the flora in particular sites if the reserves are similar in size, location, *etc* and if recording methods are similar. Two floral surveys have been done each at Woodman Point (80 ha) and Port Kennedy (1000 ha), which are cuspate forelands lying 18 km north and 9 km south of Shoalwater Bay respectively. Sixty-six native species were listed for Woodman Point by Powell & Emberson (1981) and a total of 161 species, of which 94 were native, by Keighery (2001). Fifty-five species, of which 46 were native, were recorded for Port Kennedy, excluding those listed as wetland species (Trudgen 1988). A single list of 240 species, of which 172 were native, for the wider Port Kennedy area (Keighery & Keighery 1993) was not useful for comparison.

The 18 core species found in all three Shoalwater Bay areas also occurred at Woodman Point and Port Kennedy, apart from *Alyxia buxifolia* at Woodman Point and *Clematis linearifolia* at Port Kennedy. However 12 native species were recorded at both Woodman Point and Port Kennedy that were not found at Shoalwater Bay: *Acacia lasiocarpa, Callitris preissii, Dianella revoluta, Diplolaena dampieri, Gompholobium tomentosum, Hemiandra pungens, Kennedia prostrata, Leucopogon parviflorus, Desmocladus flexuosus, Melaleuca systena, Phyllanthus calycinus* and *Schoenus grandiflorus*. Certainly some of these species could have occurred at one or other of the mainland Shoalwater Bay sites. The disparity between the three Shoalwater sites and the difference in size between them and the much more extensive Woodman Point and Port Kennedy areas makes further comparison unhelpful.

The three Shoalwater reserves surveyed are in close proximity to one another and their geology is similar, but the mainland reserves differ from the islands in that the ecosystems have different dynamics and are subject to different disturbance processes. Fire has only been a problem at Point Peron. Nutrient enrichment of the soil dominates the ecology of seabird islands, where there is a massive nutrient subsidy from the ocean via seabirds that feed at sea and deposit guano on the islands (Anderson & Polis 1999; Mizutani & Wada 1988). On the mainland, urban bushland remnants generally derive any additional nutrients from neighbouring parks and gardens. Weed invasion is of major importance in all three reserves. A very high proportion of the species recorded are aliens, 63% 53% and 52% for Mersey Point, Point Peron and the islands respectively. This compares with only 26% for the Perth region (Marchant *et al.* 1987) and 12% for Western Australia as a whole (Paczkowska & Chapman 2000). Many of these introduced species are widespread annual herbs and grasses such as **Lagurus ovatus*, **Euphorbia terracina*, **E. peplus* and **Sonchus oleraceus* that invade following disturbance.

Mersey Point

There is a swale beside the road down the eastern side of Mersey Point Reserve which is used for dumping garden rubbish. Heaps of lawn cuttings and garden clippings of various ages can be found here, with the garden plants and introduced succulents listed for Mersey Point, opposite the gardens from which they originated. Some species such as **Nerium oleander* could have been planted originally in landscaping works. The lawned areas (watered, fertilised and mown) are at risk of infiltrating adjacent bushland, and like the composting rubbish are capable of changing the nutrient balance of the bushland.

The disturbance of the broad strip of foreshore sands beside the beach comes mainly from the wind and sea. This area is thinly covered by four perennial species, two native spinifex grasses of foredunes and **Pelargonium capitatum* and **Trachyandra divaricata* which are coastal species that colonise denuded areas.

Point Peron

Frequent fires have occurred in recent years at Point Peron (11 during the summer of 1999-2000; B Green, unpublished observations). These appear to be the result of arson, and there was associated vehicle activity and destruction of fences. Point Peron is less overlooked by the suburbs of Rockingham than the other two reserves and this isolation may make it more vulnerable to vandalism.

Comparison of our results with a previous vegetation survey (Keating & Trudgen 1986) makes it possible to gauge the effects of fires. Unfortunately few introduced species were included in the 1986 species lists, but vegetation communities were mapped. In 1986 the most widespread vegetation community at Point Peron was *Acacia rostellifera-Alyxia buxifolia* heath, covering about 40% of the area. This was a very mixed community with a further 16 native shrubs, herbs and creepers listed in

addition to the two dominant species. Today little of this mixed native heath survives. Under a regime of frequent burning, annuals and species that can survive fire can be advantaged. *Acacia rostellifera* which can be rejuvenated by fire, as it resprouts from damaged trunks and from underground parts, becomes senescent and starts to die out after about 20 years (McArthur 1996). At Point Peron, *Acacia rostellifera* now covers most of the eastern dunes area, with introduced alien annuals, particularly **Euphorbia terracina* and grasses forming much of the understorey. Most of the *Acacia* is young regrowth vegetation, and it is very dense in some sheltered areas.

It cannot be stated that any native species have disappeared or appeared as a result of fire, particularly as some species may always be overlooked by researchers, but three shrubs, *Leucopogon parviflorus*, *Acacia lasiocarpa* and *Diplolaena dampiera* were listed by Keating & Trudgen (1986) and not found in our survey, and *Dodonaea aptera* was unlisted by these authors but was found in our survey. The high number of introduced annual grasses and herbs recorded in our survey could well be associated with the recent fires. These species now dominate the vegetation in some areas and dominate the understorey in others. Such weeds not only invade burned areas but also die back in summer forming tinder that makes the area still more fire-prone. At least one species, **Echium plantagineum*, was probably brought in by earthmoving machinery during rehabilitation efforts.

The islands

Comparison with earlier vegetation surveys showed that on Penguin Island 12% of native species had been lost over the past 40 years but on the small islands the loss had been much more dramatic, 67% on Seal Island, 82% on Bird Island and 43% on Middle Shag Island (Rippey *et al.* 1998). The trend, which is continuing, is not the direct result of human action, but is primarily due to changes in soil nutrient levels and trampling during nesting by increasing numbers of cormorants, and since 1999 a group of pelicans. The vegetation cycle described by Gillham (1961) is still identifiable on the southern and eastern parts of Penguin Island, where these species do not nest. Here the vegetation is damaged and enriched in patches where smaller seabirds such as silver gulls, and little penguins (*Eudyptula minor*) nest, giving annual weeds an opportunity to grow until the dominant perennials such as *Rhagodia baccata* reestablish. However areas used for nesting by the major guano producing bird species of the region, pelicans and cormorants, have undergone a radical vegetation change. On the north of Penguin Island and on the small islands, the native vegetation has virtually disappeared with the exception of *Nitraria billardierei* on the talus slopes. **Malva dendromorpha* often dominates as 2 m high thickets. On the islands of Brittany (France), this species is regarded as being more tolerant of high guano levels than any other (Gehu & Gehu-Franck 1961). Annual weeds such as **Lolium rigidum*, **Bromus diandrus*, **Urtica urens*, **Chenopodium album* and **C. murale* are also common. The Gillham cycle has been replaced by a situation where **M. dendromorpha* and annual alien species dominate and persist. Unfortunately this makes the islands vulnerable to erosion as the annuals disappear completely during the hot, dry and windy summer months, and **M. dendromorpha* dies back to a clump of leaves on the top of a bare stem, with little or no understorey.

Change in vegetation as a result of nesting by seabirds is well recognised. For example on the north-east coast of Scotland in sites used by herring gulls *Larus argentatus* (Sobey & Kenworthy 1979), and on the Riou archipelago off Marseilles (France) where there has been a population explosion of yellow legged gulls *Larus cachinnans* (Vidal *et al.* 1998), trampling, manuring, digging, and collection of nest material has resulted in loss of species diversity and dominance by annual and ruderal species. In Scotland it was noted that no annuals were present in non-affected sites; in the French study the disappearance of indigenous species was emphasised.

The native *Malva australiana* is being supplanted by **M. dendromorpha*, and by 2002 Middle Shag Island was the only Shoalwater Bay island on which it persisted. This *M. australiana* of the island variety (formerly *Lavatera plebeia* var *tomentosa*) is one of only 18 'obligate/semi-obligate ornithocoprophilic' vascular plant species in the world (Yugovic 1998). **Lycium ferocissimum* (African boxthorn) is a dangerous introduction capable of changing the character of the island vegetation entirely.

Management implications

Invasion by weeds is the most obvious problem of the Shoalwater reserves. Current thinking suggests that if causes of invasion are understood and addressed then the chances of success are greater than if weeds are removed (Adair & Groves 1998). Identification of the factors that make a site vulnerable to invasion, the degree of disturbance, and its management may lead to more effective control programmes (Hobbs & Humphries 1995). Early control of weeds is seldom possible because of the difficulty of predicting which plants will become pests (Csurhes & Edwards, 1998). Panetta (1993) suggests that the best indicator is their weediness elsewhere. *Malva dendromorpha*, however, is not considered troublesome outside Australia, although it has caused concern on Mud Islands in Victoria and on West and Wright Islands in South Australia (Rippey *et al.* 2002b). In the two mainland reserves at Shoalwater Bay much of the disturbance and weed introduction is of human origin, and in such situations an accepted approach is to strive for community awareness and involvement. Practical measures that can be of help include the delineation of lawned areas with paths or fences to maintain discrete recreation areas. Fences can prevent dumping if all else fails. Species planted in landscaping enterprises should be selected with care as many of those that establish easily can readily naturalise.

The pre-European fire regime is not known. Very frequent fires are not desirable, but occasional fires benefit many native species, and in addition, controlled fires are useful for reducing fuel loads to prevent major fires. Fire management can thus be a compromise between the needs of native flora and safety concerns (Hobbs 1995b). Well known management techniques for sites such as Point Peron where arson is the cause of fires, are education and community watch, together with weed control, the use of buffer zones or firebreaks, and control of wildfires that do occur.

On the islands, where increased numbers of large seabirds nest regularly or continuously, there is no point in attempting to restore the pre-existing native vegetation. Revegetation efforts would best be approached using only those native species which are tolerant of very high guano levels such as *Malva australiana, Carpobrotus virescens* in rocky areas and *Nitraria billardierei*. Removal of **Malva dendromorpha*, the seeds of which have a prolonged dormancy, requires a long-term commitment and would have to be carried out on all islands and the wider mainland coastline to prevent reintroduction.

M. australiana of the island variety is an attractive native species with limited geographical distribution, capable of existing in enriched soils, and it would be regrettable to lose it.

Acknowledgements: We are indebted to Coastwatch/Coastcare for grants which were used in part to fund this study. Grateful thanks go to the Friends of the Shoalwater Islands Marine Park (FSIMP) and CALM volunteers who participated in the actual field work of collecting specimens. CALM rangers T Goodlich and M Banks kindly ferried us to the islands when necessary. The West Australian Herbarium identified many of our specimens as part of the Regional Herbaria Program. We would also like to thank Dr P Armstrong of the Department of Geography (University of Western Australia) who read the manuscript and gave valuable comments.

References

Adair R J & Groves R H 1998 Impact of Environmental Weeds on Diversity: A Review and Development of a Methodology. Biodiversity Group, Environment Australia, Canberra.

Anderson W B & Polis G A 1999 Nutrient fluxes from water to land: seabirds affect plant nutrient status on Gulf of California islands. Oecologia 118:324-332.

Anon 1999 Environmental Weed Strategy for Western Australia. Department of Conservation and Land Management, Perth.

Anon 2000 Bush Forever. WA Planning Commission, Government of Western Australia, Perth.

Bodkin F 1993 Encyclopaedia Botanica. The Essential Reference Guide to Native and Exotic Plants in Australia. HarperCollins, Sydney.

Briggs I 1984 A perspective on small reserve management. In: The Management of Small Bush Areas in the Perth Metropolitan Region (ed S A Moore). Department of Fisheries and Wildlife, Perth, 101-111.

Chape S 1984 Penguin Island Draft Management Plan. National Parks Authority and Department of Conservation and Land Management, Perth.

Csurhes S & Edwards R 1998 Potential environmental weeds in Australia. Biodiversity Group, Environment Australia, Canberra.

Davis M A, Grime J P & Thomson K 2000 Fluctuating resources in plant communities: a general theory of invasibility. Journal of Ecology 88:528-534.

Dixon J, Connell S, Bailey S & Keenan C 1994 The Perth Environment Project and an inventory of Perth's remnant native vegetation. In: A Vision for a Greener City (ed M Scheltema). National Greening Australia, Perth, 57-67.

Dunlop J N, Klomp N I & Wooller R D 1988 Seabird Islands Penguin Island, Shoalwater Bay, Western Australia. Corella 12:93-98.

Ford J 1985 Summary of Aboriginal use of fire and current impact of fire on major vegetation formations. In: Fire Ecology and Management in Western Australian Ecosystems, Report 14 (ed J Ford). WAIT Environmental Studies Group, Perth, 5-6.

Gehu J-M & Gehu-Franck J 1961 Recherches sur la vegetation et le sol de la reserve de l'Ile des Landes (I - IV), et de quelques ilots de la cote Nord-Bretagne. Incidences de l'avifaune marine sur la flore. Bulletin du Laboratoire maritime de Dinard 47:84-99.

Gillham M E 1961 Alteration of the breeding habitat by seabirds and seals in Western Australia. Journal of Ecology 49:289-300.

Hingston F J & Gailitis V 1976 The geographic variation of salt precipitated over Western Australia. Australian Journal of Soil Research 14:319-335.

Hobbs R J & Huenneke L F 1992 Disturbance, diversity, and invasions: implications for conservation. Conservation Biology 6:324-337.

Hobbs R 1995a Fertilisers and garden refuse. In: Managing Perth's Bushlands (eds M Scheltema & J Harris). Greening Western Australia, Perth, 149.

Hobbs R 1995b Fire. In: Managing Perth's Bushlands (eds M Scheltema & J Harris). Greening Western Australia, Perth, 145-148.

Hobbs R J 2000. Ecological repair following biotic invasions. In: Best Management Practices for Preventing and Controlling Invasive Alien Species (eds G Preston, G Brown & E van Wyk). Working for Water Programme, Cape Town, 181-188.

Hobbs R J & Humphries S E 1995 An integrated approach to the ecology and management of plant invasions. Conservation Biology 9:761-770.

Hobbs R J & Saunders D A 1995 Invasive weeds: prevention is the key. In: Invasive Weeds and Regenerating Ecosystems in Western Australia (ed G Burke). Murdoch University, Perth, Western Australia, 13-17.

Humphries S E, Groves R H & Mitchell D S 1991 Plant invasions of Australian ecosystems: a status review and management directions. Kowari 2:1-134.

Hussey B M J, Keighery G J, Cousens R D, Dodd J & Lloyd S D 1997 Western Weeds; A Guide to the Weeds of Western Australia. The Plant Protection Society of Western Australia, Victoria Park, Western Australia.

Keating C & Trudgen M 1986 A Flora and Vegetation Survey of the Point Peron - Lake Richmond Area. State Planning Commission, Perth.

Keighery G J & Keighery B J 1993 Part IX: The flora of three coastal bushland areas (System 6 areas M 46, M 91 and M106) in the Perth metropolitan area. In: Floristics of Reserves and Bushland Areas of the Perth Region (System 6) Parts V-IX (eds G J Keighery & B J Keighery). Wildflower Society of WA, Nedlands, Western Australia, 71-85.

Keighery G 1994 How many weeds? In: Invasive Weeds and Regenerating Ecosystems in Western Australia (ed G Burke). Murdoch University, Perth, Western Australia, 8-12.

Keighery G 2001 Vascular Flora of Woodman Point Nature Reserve. Department of Conservation and Land Management, Wildlife Research Centre, Perth.

Mack R N, Simberloff D, Lonsdale W M, Evans H, Clout M & Bazzaz F A 2000 Biotic invasions: causes, epidemiology, global consequences, and control. Ecological Applications 10:689-710.

Marchant N G, Wheeler J R, Rye B L, Bennett E M, Lander N S & Macfarlane T D 1987 Flora of the Perth Region. Western Australian Herbarium, Perth.

McArthur W M 1996 The Vegetation Communities and Some Aspects of Landscape Management of Garden Island, Western Australia. HMAS Stirling, Department of Defence, Perth.

Mizutani H & Wada E 1988 Nitrogen and carbon isotope ratios in seabird rookeries and their ecological implications. Ecology 69:340-349.

Paczkowska G & Chapman A R 2000 The Western Australian Flora. A Descriptive Catalogue. Wildflower Society of

Western Australia, Western Australian Herbarium and Botanic Gardens and Parks Authority, Perth.

Panetta F D 1993 A system of assessing proposed plant introductions for weed potential. Plant Protection Quarterly 8:10-14.

Piggott J P & Loneragan W A 1995 Fire and human disturbance regimes and impacts on plant communities at the Star Swamp Bushland Reserve. In: Burning our Bushland (ed J Harris). Urban Bushland Council (WA), Perth, 19-24.

Powell R & Emberson J 1981 Woodman Point: A Relic of Perth's Coastal Vegetation. Artlook, Perth.

Rippey E, Rippey J, Dunlop N, Durant C, Green B & Lord J 1998 The changing flora of the Shoalwater Bay Islands. The Western Australian Naturalist 22:81-103.

Rippey E, Rippey J J & Dunlop N J 2002a Increasing numbers of pied cormorants breeding on the islands off Perth, Western Australia and consequences for the vegetation. Corella 26:61-64.

Rippey ME, Rippey J J & Dunlop N 2002b Management of indigenous and alien Malvaceae on islands near Perth, Western Australia. In: Turning the Tide: The Eradication of Invasive Species (eds C R Veitch & M N Clout). IUCN SSC Invasive Specialist Group. IUCN, Gland, Switzerland & Cambridge, UK, 254-259.

Robley J 1983 The bush fire risk in the Perth metropolitan region. In: The Management of Small Bush Areas in the Perth Metropolitan Region (ed S A Moore). Department of Fisheries and Wildlife, Perth, 6-10.

Serventy V N & White S R 1943 Birds of Warnboro Sound, Western Australia. The Emu 43:81-95.

Sobey DG & Kenworthy JB 1979 The relationship between herring gulls and the vegetation of their breeding colonies. Journal of Ecology 67: 469-496.

Trudgen M 1988 Vegetation of the Point Becher area. In: Port Kennedy Regional Recreation Centre Environmental Review and Management Programme. Unpublished report to Port Kennedy Joint Venture (eds Binnie & Partners). Port Kennedy Joint Venture, Perth, D3-D28.

Vidal E, Medail, F, Tatoni, T, Vidal, P & Roche, P 1998 Functional analysis of the newly established plants induced by nesting gulls on Riou archipelago (Marseille, France). Acta Oecologica 19:241-250.

Wycherley P 1984 People, fire and weeds: can the vicious spiral be broken? In: The Management of Small Bush Areas in the Perth Metropolitan Region (ed S A Moore). Department of Fisheries and Wildlife, Perth, 11-17.

Yugovic J 1998 Vegetation dynamics of a bird-dominated island ecosystem (Mud Islands, Port Phillip Bay, Australia). PhD Thesis, Monash University, Melbourne.

Appendix.

Species list for the Shoalwater Islands, Mersey Point Reserve and Point Peron (list for islands from Rippey *et al.* 1998). * denotes introduced species. p denotes species present.

Plant families	Plant Names	Mersey Pt	Pt Peron	Islands
Agavaceae	* *Agave americana*	p	p	
	* *Agave attenuata*	p		
	* *Sansevieria trifasciata*	p		
Aizoaceae	* *Carpobrotus edulis*		p	
	Carpobrotus virescens	p	p	p
	* *Galenia pubescens*		p	p
	* *Tetragonia decumbens*	p	p	p
	Tetragonia implexicoma		p	p
Amaryllidaceae	* *Agapanthus praecox*	p		
Anacardiaceae	* *Schinus terebinthifolia*	p		
Apiaceae	*Apium prostratum*			p
Apocynaceae	*Alyxia buxifolia*	p	p	p
	* *Nerium oleander*	p		
Araucariaceae	* *Araucaria heterophylla*	p		p
Asphodelaceae	* *Trachyandra divaricata*	p	p	p
	* *Asphodelus fistulosus*		p	
Asteraceae	* *Arctotheca calendula*	p	p	p
	* *Arctotheca populifolia*		p	
	* *Arctotis stoechadifolia*		p	
	* *Conyza* sp	p	p	
	* *Hypochaeris* sp		p	
	Leucophyta brownii			p
	Olearia axillaris	p	p	p
	* *Osteospermum ecklonis*	p		
	Ozothamnus cordatus		p	p
	Senecio lautus	p	p	p
	* *Senecio tamoides*	p		p
	* *Sonchus oleraceus*	p	p	p
Boraginaceae	* *Echium plantagineum*		p	
Brassicaceae	* *Brassica rapa*			p
	* *Brassica tournefortii*	p		
	* *Cakile maritima*	p	p	p
	Lepidium foliosum			p
	* *Raphanus raphanistrum*		p	p
	* *Sisymbrium orientale*	p		p
Cactaceae	* *Opuntia stricta*	p		
Caryophyllaceae	* *Polycarpon tetraphyllum*			p
	* *Sagina maritima*			p
Chenopodiaceae	* *Atriplex prostrata*			p
	* *Chenopodium album*			p
	* *Chenopodium ambrosioides*			p
	* *Chenopodium murale*			p
	Enchylaena tomentosa		p	p
	Rhagodia baccata	p	p	p
	Salsola tragus	p	p	
	Sarcocornia quinqueflora			p
	Sarcocornia sp		p	
	Threlkeldia diffusa	p	p	p
Convolvulaceae	* *Cuscuta epithymum*	p		
	Wilsonia backhousei		p	p
Crassulaceae	* *Aeonium arboreum*	p		
	* *Cotyledon orbiculata*	p		
	* *Crassula glomerata*	p	p	
	Crassula closiana			p
Cyperaceae	*Isolepis nodosa*	p	p	
	Lepidosperma gladiatum	p	p	p
Dasypogonaceae	*Acanthocarpus preissii*	p	p	p
	Lomandra maritima		p	
Dilleniaceae	*Hibbertia cuneiformis*	p		
Dipsacaceae	* *Scabiosa atropurpurea*		p	
Euphorbiaceae	* *Euphorbia paralias*		p	
	* *Euphorbia peplus*	p	p	p
	* *Euphorbia terracina*	p	p	p
	* *Euphorbia* sp	p		
Frankeniaceae	*Frankenia pauciflora*		p	p

Plant families	Plant Names	Mersey Pt	Pt Peron	Islands
Fumariaceae	*Fumaria capreolata	p	p	p
	*Fumaria muralis		p	
Geraniaceae	*Erodium moschatum			p
	*Pelargonium capitatum	p	p	p
Goodeniaceae	Scaevola crassifolia	p	p	p
Haemodoraceae	Conostylis candicans	p	p	p
Iridaceae	*Romulea rosea	p	p	p
Lamiaceae	*Lavandula sp	p		
Lauraceae	Cassytha racemosa		p	p
Malvaceae	*Malva dendromorpha		p	p
	*Malva linnaei		p	p
	Malva australiana			p
	*Malva parviflora			p
Mimosaceae	Acacia cochlearis	p	p	
	Acacia cyclops	p	p	p
	Acacia rostellifera	p	p	p
	Acacia saligna	p		
Moraceae	*Ficus sp		p	p
Myoporaceae	Eremophila glabra		p	p
	Myoporum insulare	p	p	p
Myrtaceae	Agonis flexuosa	p		p
	*Eucalyptus erythrocorys	p		
	*Eucalyptus gomphocephala	p	p	p
	*Eucalyptus utilis	p	p	p
	*Leptospermum laevigatum	p	p	
	Melaleuca huegelii		p	
	Melaleuca lanceolata		p	p
	*Melaleuca nesophila	p		p
Oleaceae	*Olea europea	p		
Onagraceae	*Oenothera drummondii	p	p	
Oxalidaceae	*Oxalis pes-caprae	p		p
Papilionaceae	Hardenbergia comptoneana	p	p	p
	Jacksonia furcellata	p		
	*Lupinus consentinii		p	
	*Lupinus sp	p		
	*Medicago polymorpha	p	p	
	*Melilotus indicus			p
	Templetonia retusa		p	
Pittosporaceae	Pittosporum ligustrifolium		p	p
Poaceae	*Ammophila arenaria		p	
	*Arundo donax	p		
	Austrostipa elegantissima		p	p
	Austrostipa flavescens			p
	*Avena barbata	p	p	
	*Avena fatua		p	p
	*Brachypodium distachyon		p	
	*Bromus diandrus			p
	*Bromus sp		p	
	*Cynodon dactylon	p		
	*Ehrharta longiflora			p
	*Ehrharta sp		p	
	*Hordeum leporinum		p	p
	*Lagurus ovatus	p	p	p
	*Lolium perenne			p
	*Lolium rigidum		p	p
	*Parapholis incurva		p	p
	*Poa annua			p
	Poa poiformis		p	
	Spinifex hirsutus	p	p	p
	Spinifex longifolius	p	p	p
	Sporobolus virginicus			p
	*Stenotaphrum secundatum	p	p	p
Polygonaceae	Muehlenbeckia adpressa		p	p
Primulaceae	*Anagallis arvensis	p	p	p
Ranunculaceae	Clematis linearifolia	p	p	p
Rhamnaceae	*Rhamnus alaternus	p		
	Spyridium globulosum	p	p	p
Santalaceae	Exocarpus sparteus			p
	*Leptomeria preissiana	p		

Plant families	Plant Names	Mersey Pt	Pt Peron	Islands
Sapindaceae	*Dodonaea aptera*		p	
Solanaceae	*Anthocercis ilicifolia*		p	
	* *Lycium ferocissimum*			p
	* *Solanum linneanum*	p		
	* *Solanum nigrum*			p
	Solanum symonii		p	
Tamaricaceae	* *Tamarix* sp			p
Tropaeolaceae	* *Tropaeolum majus*	p		
Urticaceae	*Parietaria* sp		p	p
	* *Urtica urens*			p
Verbenaceae	* *Lantana camara*	p		
Zygophyllaceae	*Nitraria billardierei*	p		p
Total	**91 146**	**76**	**86**	**88**